Electric Power Systems Research 162 (2018) 10–22

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Modelling and controlling of PV connected quasi Z-source cascaded multilevel inverter system: An HACSNN based control approach

V.V. Rajasegharan[a,*], L. Premalatha[b], R. Rengaraj[c]

[a] Anand Institute of Higher Technology, India
[b] VIT University, India
[c] SSN College of Engineering, India

ARTICLE INFO

Keywords:
ACS algorithm
ANN
QZS-CMI
PV
Voltage
Grid tie current

ABSTRACT

In this paper, the modelling and controller design for quasi-Z source cascaded multilevel inverter (QZS-CMI) based three-phase grid-tie photovoltaic (PV) power system is presented. The control scheme of 3-phase QZS-CMI is designed as two phases and regulates the source PV voltage and output grid current. Here, the first phase utilized Adaptive Cuckoo Search (ACS) algorithm for determining the total PV voltage and the second phase utilized CS algorithm with artificial neural network (ANN) to extract the reference current of grid. In first phase, the ACS algorithm engendered the tuning parameters of the PI controller based on the variation of the PV voltage. The second phase ANN is trained offline manner with the exact dataset prepared by the CS technique and it ensures the grid current control. The proposed method is refined for regulating the DC link voltages and extracting the grid currents. The proposed method based QZS-CMI synchronizes the shoot through duty ratio, reduces the modulation burden, regulates the dc link voltage, current and frequency conditions. By using the proposed method, all presented QZS-H-bridge inverter (HBI) modules achieves the grid-tie current injection and independent maximum power point tracking (MPPT) using system level control. The proposed method based QZS-CMI is designed with MATLAB/Simulink platform and their performances are evaluated with traditional techniques.

1. Introduction

As of late, multilevel inverter topologies applying to PV systems are attaining progressive consideration because of the tremendous power-scale and high voltage demands [1]. Slighter voltage changes, intrinsically, discerning switching frequency and diminution of common mode voltages and discerning output harmonic substance are the assets of this application [2]. PV power generation has a tremendous potential in order to endow as a hygienic and imperishable renewable energy source [3]. The output power of the PV arrays is debilitated to a jumbo extent [4] due to environmental circumstances the capricious temperature will change and solar irradiance. Analytical procedures have been proposed to provoke pulse patterns at fundamental frequency and compactness [5] in order to enlarge the efficiency of multilevel converters and then to trim down the power losses.

Linked in a poured way [6], the total harmonic distortion of the output may be miniaturized by the hesitant multilevel inverter (MLI) that consists of H-bridges. But it has multitudinal limitations [7]. In order to overawe the glitches in PV applications, the Z source inverter (ZSI) and quasi-Z source inverter (QZSI) based CMI PV power systems have been ingrained. The ascendancies over the ZSI [8] are truncated component ratings, embellished reliability and constant current from the input DC source. Capacitor inductor network having voltage-boost and voltage-buck capabilities [9,10] is in harness by a single-stage power converter. Voltage boost and power conversion can be impelled contemporaneously in a single stage without wrecking the inverter [11] in order to redeem the reliability due to the shoot-through cases.

The PV connected quasi-Z source (QZS) network based CHB module has several ascendancies like PV string voltage boost, sovereign tracking MPP of each PV string and guardianship an equivalent DC link voltage for each H-bridge inverter module [12]. Also the High-quality staircase output voltage, sovereign DC-link voltage compensation in a

Abbreviations: QZS-CMI, quasi-Z source cascaded multilevel inverter; PV, photo-voltaic; ACS, Adaptive Cuckoo Search algorithm; ANN, artificial neural network; HBI, H-bridge inverter; MPPT, maximum power point tracking; MLI, multi-level inverter; ZSI, Z source inverter; CHB, cascaded H-bridge; SNN, simulated neural network; HACSNN, hybrid Adaptive Cuckoo Search neural network; MCC, modular cascaded converter; DC, direct current; AC, alternating current; CS, Cuckoo Search algorithm; PI, proportional integral; GA, genetic algorithm; FOPID, fractional order proportional integral and derivative; BP, back propagation

* Corresponding author.
E-mail address: rajasegharanvv.eee@aiht.ac.in (R. V.V.).

https://doi.org/10.1016/j.epsr.2018.04.020
Received 14 July 2017; Received in revised form 30 January 2018; Accepted 27 April 2018

single-stage power transmogrification and sovereign power inventory control with high reliability [13,14] are the disseverance of this topology. Based on a connectionist approach, information processing can be done to enumerate an imitation neural network (ANN) or fictitious neural network (SNN). Selective harmonic elimination is achieved by Newton–Raphson method. This paper introduces an HACSNN control approach and modelling for PV connected QZS-MLI and the effective performance are analyzed. The quiescence of paper is organized by succeeding: throughout Section 2 the contempt analysis works is recapped; throughout Section 3 the proposed work expatiates the grabber. The suggested technique gives good results and the affiliated discussions are provided in Section 4; well as Section 5 finishes the paper.

2. Recent research works: a brief review

Based on the quasi-Z-source inverters (QZSI) of a renewable system using various techniques numerous research works antecedent exist in literature. Several works are reviewed here. As a candidate topology for the photovoltaic module-level power electronics applications high-performance QZS series resonant DC–DC converter was presented by Vinnikov et al. [15]. A massive input voltage and load regulation range is reformed by a multimode operation. Owing to its additional state the conventional inverter adding the Z-source inverter into wireless power transfer systems helps to offer extra control strategies and was discussed by Wang et al. [16]. A predictive control strategy for a three-phase QZSI is proposed by Mosa et al. [17] gratifying the requirements devoid of adding any supplementary layers of control loops. As a narrative solution for photovoltaic applications a three-phase three-level neutral-point-clamped quasi-Z-source inverter has been proposed by Husev et al. [18]. The topology was derived by combining properties of the QZS networks with those of three-level neutral-point-clamped inverters. A quasi-Z-source modular cascaded converter (QZS-MCC) for dc integration of high-power PV systems was projected by Liu et al. [19].

The modelling and scrutiny of QZS-CMI in power system is debunked in the retrospect of modern research works. For maximizing the power of the system the QZS-CMI is usually used in the PV energy resources. To overcome the snags with imbalance DC-link voltages among independent modules, QZS-CMI based PV systems were refined that inherit the advantages of conventional CMI and PV array voltage boost [20,21]. For QZS-CMI, different multi-carrier bipolar PWM techniques are refined and concentrated on the parameter design of the QZS-CMI. An efficient technique is needed to improve the modelling and control design of QZS-CMI for attaining the optimal results of the PV system.

3. Description of the system with proposed converter

An HACSNN based control strategy for PV connected QZS-CMI system is effectively proposed in this paper. The following figure depicts the block diagram of the QZS connected CMI with proposed controller. The block diagram consists of PV sources, QZS-CMI, grid and load. The presented structure is the n-level CMI with n-level PV sources and QZS for each level which is obvious from the block diagram. The AC power to the grid is ensured by the filtered and boosted DC power, which is directly connected to the grid via H-bridge.

Using the proposed controller, the control pulse is integrated based on the irradiation variation in the PV. In the proposed methodology, two algorithms are utilized for controlling the process of converter such as ACS and CS with ANN. The ACS is applied to the phase I process for controlling the total PV voltage control, which generates the control signals based on the PV voltage deviations. In the phase II, the CS algorithm with ANN ensures to reduce the grid-tie current variation and it is affirmed for the grid current control. The circuit structure of the QZS-CMI with grid and the QZS shoot through state and QZS non-shoot through state is described in Fig. 1.

N-number of module is presented in the above circuit diagram. PV panels, QZS, H-bridge are included in each module. The QZS presented in each module is applied with the DC power which is generated by the PV source. The output is connected to the grid after giving the stepped waveform by the voltage generators when the DC signal is converted to AC by multilevel inverters. With the help of proposed method, the modelling and control strategy of the system is investigated. The following section analyzes the detailed description. The QZS [22] connected with multilevel inverter [23–25] mathematical modelling and the analysis is found.

4. Control methodology

The control strategy of PV with QZS–CMI is considered as two phases like phase I and phase II. Voltage control loop and current control loop are the first phase of the system and the second phase of the system respectively. The grid current and DC link voltage are evaluated using the resting control loops. ACS algorithm and CS with ANN techniques are used to analyze the two main control loops. Fig. 2 illustrates the control methodology structure. Before that, based on their control loop constraints, the objective function of the proposed algorithm is defined.

4.1. In phase I

The total PV array voltage control is handled by using the proposed phase I process based PI controller. Using the ACS algorithm, the gain parameters are optimally tuned for the enhancement of PI controller. The performance of PV is tracked and the reference voltage of PV array is evaluated here. Using the following equations, the step by step calculations are determined.

Initially, the voltage of PV is scrutinised using Eq. (1),

$$V_{PVxk}(s) = \frac{1}{C_{p^x}}[I_{PVxk}(s) - I_{L1xk}(s)] \tag{1}$$

where $x = a, b, c \; and \; k = \{1,2,...,n\}$, V_{PVxk}, I_{PVxk} and I_{L1xk} are the voltages of PV panel, currents of the PV panel and the inductor L1 of the kth module in phase x, C_P is the terminal capacitance. After that, the power equation of QZS-HBI module is evaluated as well as the corresponding input power is matched with the output power. The power is evaluated using Eq. (2) during the non shoot-through state.

$$\frac{\hat{i}_{gx}\hat{v}_{Hxk}}{2} = v_{dcxk}\bar{i}_{dcxk} = v_{PVxk}\bar{i}_{LIxk\,nsh} \tag{2}$$

From the above equations, the power of *k*th QZS-HBI module has been scrutinised. Where, the symbol '^' and '_' denotes the amplitude and average values respectively. $\hat{i}_{gx}$ is the grid tie current of phase x, $\hat{v}_{Hxk}$ is the kth module output voltage of phase x. v_{dcxk} and $\bar{i}_{dcxk}$ is the DC-link voltage and current of phase x respectively. $\bar{i}_{L1xk\,nsh}$ is the inductor's average current L_1 in non-shoot-through state. Then the evaluation of $\bar{i}_{L1k} - nsh$ can be solved as the following

$$\bar{i}_{L1xk\,nsh} = \frac{\hat{i}_{gx}\hat{v}_{Hxk}}{2\hat{v}_{dcxk}(1 - 2D_{cyxk})} \tag{3}$$

where D_{cyxk} represents the shoot through duty cycle of the kth module in phase x. The average current of inductor L_1 can be expressed in shoot-through state as,

$$\bar{i}_{L1xk\,nsh} = i_{PVxk} \tag{4}$$

Combining Eq. (3) and (4), the inductor's average current L_1 is,

$$\bar{i}_{L1xk} = D_{cyxk}i_{PVxk} + \frac{i_{gx}(1 - D_{cyxk})\hat{v}_{Hxk}}{2\hat{v}_{dcxk}(1 - 2D_{cyxk})} \tag{5}$$

In the phase 1 process, the transfer function of the PV voltage G_{voxt} is determined and evaluated using Eq. (6),